# Factors Motivating the Adoption of BIM- based Sustainability Analysis

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**Key words:**

BIM technologies, BIM based sustainability, Environmental Assessment methods, Sustainability drivers and barriers.

## Abstract

*The delivery of sustainable and green certified buildings such as BREEAM and LEED is a highly-discussed topic with significant interest growth between the Architecture Engineering and Construction (AEC) industry. At the same time, professionals in the AEC have started to recognize the importance of the synergy between Building Information Modelling (BIM) and the assessment of green building strategies to the construction industry. Several studies demonstrated BIM as a platform for collaboration in the AEC sector in general, rather than to deliver green buildings. Thus fewer researchers have tended to investigate the external and internal problems/factors that affects the delivery of green buildings, and role of digital tools and BIM based strategy in solving them. Through thematic coding of existing literature, this paper formulates a critical review of the key drivers for the change needed in AEC industry. It maps knowledge, makes recommendations for improved collaboration, and offers general insight into the delivery of green building design. This review will act as a base to address the critical factors affecting the delivery of green buildings, and investigate how integrating BIM with sustainability aspects could overcome workflow problems towards better collaboration. The investigation concluded that the practice adoption to BIM-based applications is affected by the immature level of integration and lack of consistent framework that is based on the problems in the workflow, process and gap in communication strategies captured from the field work.*

### 1. INTRODUCTION

The Construction sector is criticised as an industry that consumes 40% of global energy consumption and waste generation, and 25% of the global water consumption (Balasubramanian and Shukla, 2017b). This had created a global interest towards delivering green buildings, which in turn had highly influenced a change of altitude of the AEC industry (Ahn *et al.*, 2013). A significant number of studies has reported problems facing a project team in delivering green buildings, which has consequently led to an increase in extra costs and time of the project (Hope and Alwan, 2012; Alwan, Greenwood and Gledson, 2015a). At the same time, BIM was identified as the reason for a paradigm shift in the AEC industry,(Taylor and Bernstein, 2009). This has developed a revolution in ways of visualizing, analysing, sharing and documenting project data amongst project teams (Ghaffarianhoseini *et al.*, 2016).

In addition, several studies have discussed problems associated with traditional project delivery and have pointed out the potential that the integration of BIM technologies and sustainability design have to enhance productivity and improve efficiency. This applies to all project stages; from briefing and design, though to construction and project operation and maintenance. (Azhar and Brown, 2009a; Stapleton, Gledson and Alwan, 2014a; Ghaffarianhoseini *et al.*, 2016; Hamada *et al.*, 2016). Also, the academics and experts in the field started to recognize the importance of the synergy between (BIM) and the assessment of green building strategies to the construction industry. In spite of, the growing BIM interest, it is observed that in practice most applications in the industry and BIM promoting events are concentrated more on the 4D and 5D applications – time and cost, with limited concern about incorporating sustainability within BIM approaches. Therefore, the purpose of this paper is to understand the reasons behind the evolution in research regarding BIM and sustainability, which created a need for bridging BIM practices and sustainability.

Most of the studies discussed the drivers and barriers of the two poles of the change in the AEC industry; BIM and green practices, by demonstrating them individually. In order to conclude what are the reasons behind the need for adoption of BIM based sustainability, as shown in Fig. 1; the evolution of the significance of its' adoption needs to be investigated. A comprehensive thematic literature was developed to identify a deeper insight into the research gaps and act as base for areas that need investigation. In addition, the paper will access the drivers for adopting BIM and sustainability approaches as catalysts for change in the industry. Finally, it will demonstrate how some barriers to delivering green buildings with the help of the potentials of BIM impact the recognition of the synergy benefits.

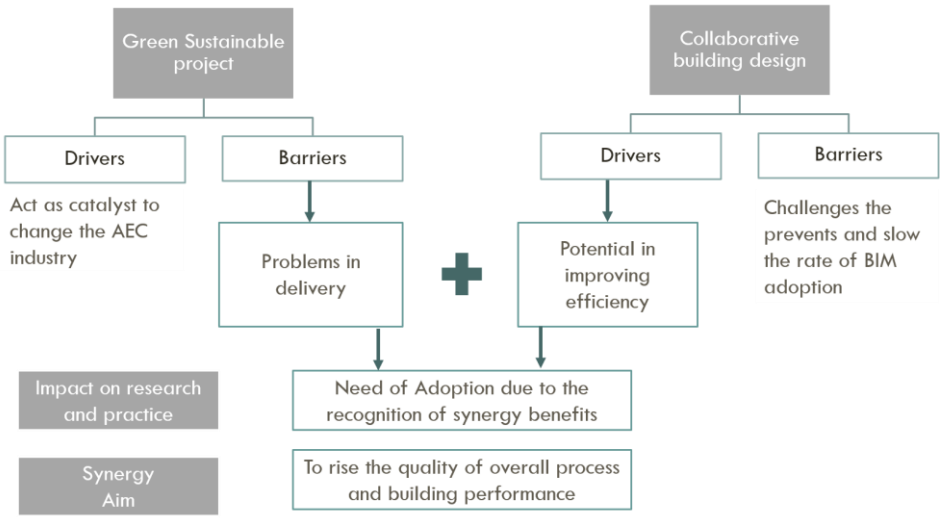


**Figure 1. The evolution of Research Significance**

## 2. RESEARCH METHOD

This section will explain the research method, which will include the criteria of the selection of papers, how they are collected and analysed. This paper formulates a critical review of existing literature through thematic coding of the key drivers affecting the

change in the industry towards BIM-based sustainability, as mentioned above. According, to the discussed motivators in the introduction shown in Fig 1, the first step was to identify the different themes mentioned in table 1. Those themes aim is to address the contribution of the synergy through understanding of the reasons behind the evolution of the benefits and challenges of the new strategies adoption. Google scholar and Scopus were used as search engines to collect relevant peer reviewed journal and conference proceedings papers that are directly related to the titles using the key works in table 1. After filtering, a total of 38 peer reviewed papers were used for the four themes to be able to categorize factors and areas of development. The third step was to draw the effect of the reviewed literature to point out its current contribution and gap of knowledge that require further work.

**Table 1 Main themes and the used search keywords**

| Main Themes | Main key words | Search key words |
|---|---|---|
| **Driving forces to deliver sustainable buildings** | Green buildings deliver, sustainable buildings, sustainable design and construction, green certified buildings , Environmental assessment methods (EAM), rating schemes/tools | + Driving forces, Motivators, demand factors, influencing adoption, promotion strategies, perceived benefits, incentives |
| **Barriers of sustainable building delivery** | | + Barriers of adoption, barriers of delivery, risks, factors, obstacles |
| **Driving Forces for Collaborative Building Design Adoption** | Green BIM, BIM based sustainability, collaborative design, Green practices in BIM | Applications , promote BIM , synergy benefits, integration, impact , potential , development |
| **Barriers of BIM-based sustainability** | | Problems, obstacles, challenges, barriers |

## 3. LITERATURE REVIEW

Understanding the evolution of the perceived benefits and the challenges of the synergy between the BIM and green practices is important to be able to point out the current contribution of BIM in delivering sustainable projects. The academic literature on both BIM and sustainable project delivery has revealed the emergence of several contrasting themes. This section will discuss and present a series of categorized factors studied in previous research on the driving forces and barriers for adopting BIM and sustainable building approach.

### 3.1 Driving forces to deliver sustainable buildings

Numerous studies have been published on the driving forces to deliver sustainable projects (Olubunmi, Bo Xia and Skitmore, 2016; Darko *et al.*, 2017)**.**These studies reported and evaluated the AEC driving forces towards green construction practices. Some of those driving forces were also applied on the increase in demand of the certified buildings using

Environmental assessment methodologies such as LEED and BREEAM. Figure 2 represents the common categories found in 6 papers that discussed and evaluated the importance of the driving forces in the AEC industry. The approaches to group those driving forces were different. For example (Balasubramanian and Shukla, 2017a) drew attention to the driving forces of green implementation and divided them into internal and external driving forces with respect to the organizations stakeholders which was developed through the literature review. Darko et al. (Darko, Zhang and Chan, 2017) grouped the drivers into corporate level, external, property-level, individual level and project level, and a survey using quantitative analysis were conducted to rate the effectiveness of those factors on the AEC industry. Ahn et al. in 2013 (Ahn *et al.*, 2013)**,** clustered the driving forces into 3 : economic, environmental, and social, but more factors were investigated and categorized; such as global and governmental pressure (Olubunmi, Bo Xia and Skitmore, 2016; Shazmin *et al.*, 2017).

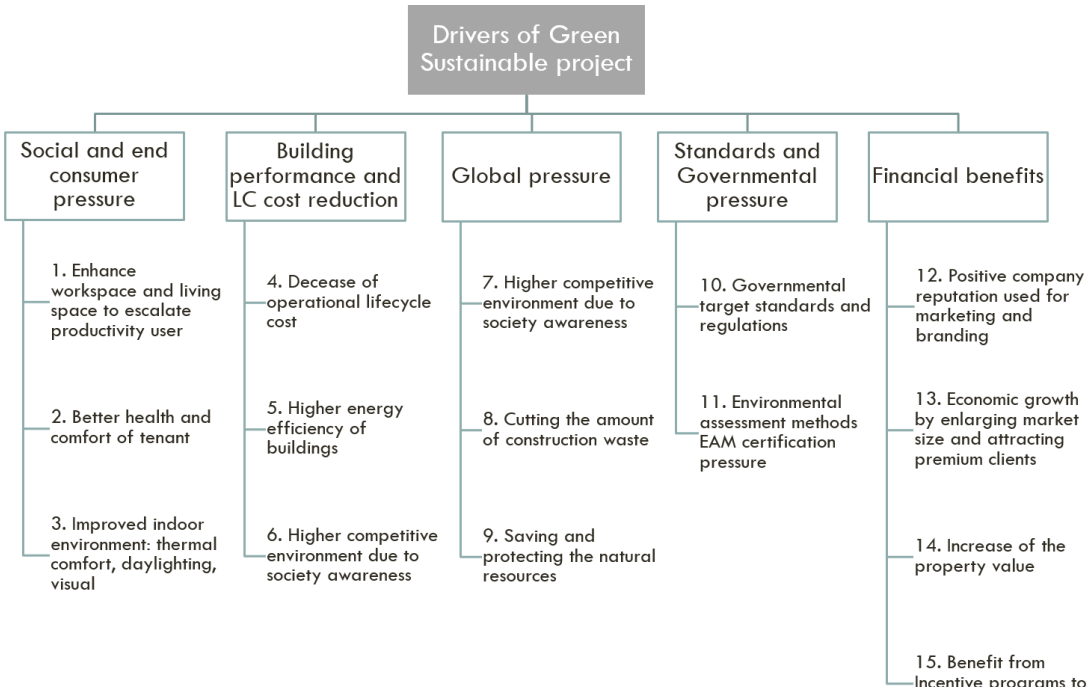


**Figure 2. The Driving Forces to deliver sustainable buildings**

The choice of the listed factors was according to the most common factors discussed among recent studies. Using different approaches such as Literature, empirical studies and quantitative analysis, the researchers were able to investigate the factors influencing the change towards green implementations in the AEC sector. However, limited studies focused on those driving forces as catalyst of change in AEC industry in the direction to BIM- based sustainability adoption. Fifteen driving forces are listed in Figure 2 under five categories: social and end consumer pressure, building performance and LC reduction, standard and governmental pressure, financial benefits to the owner and user of the property.

### 3.2 Barriers of sustainable building delivery

To be able to access the contribution of BIM in green project delivery, it is crucial to be aware of the barriers of green construction practices. It is important to know the obstacles that affects the increase in the green practices adoption, to be able to then evaluate the level of contribution of the synergy between BIM and sustainable design. The benefit of investigating the previous research discussed the barriers, that the researcher will be able to determine the areas of improvements to overcome some barriers and at the same time avoid claiming that the integration will solve all problems in the industry towards green practices. Figure 3, presents an overview on the themes investigated before in previous studies on the barriers of green project deliver. The existing literature of the barriers for delivering sustainable building has focused more on the current industry deficiency, risk of investments and initial costs and also of the rigidity of change in practices. Numerous research have attempted to explain the influence of those obstacles on the adoption of green strategies. However, a systematic understanding of how BIM based practices contributes into the reduction of the influence of some barriers is still lacking, especially on the effect of reducing cost by using BIM technologies on the long run.

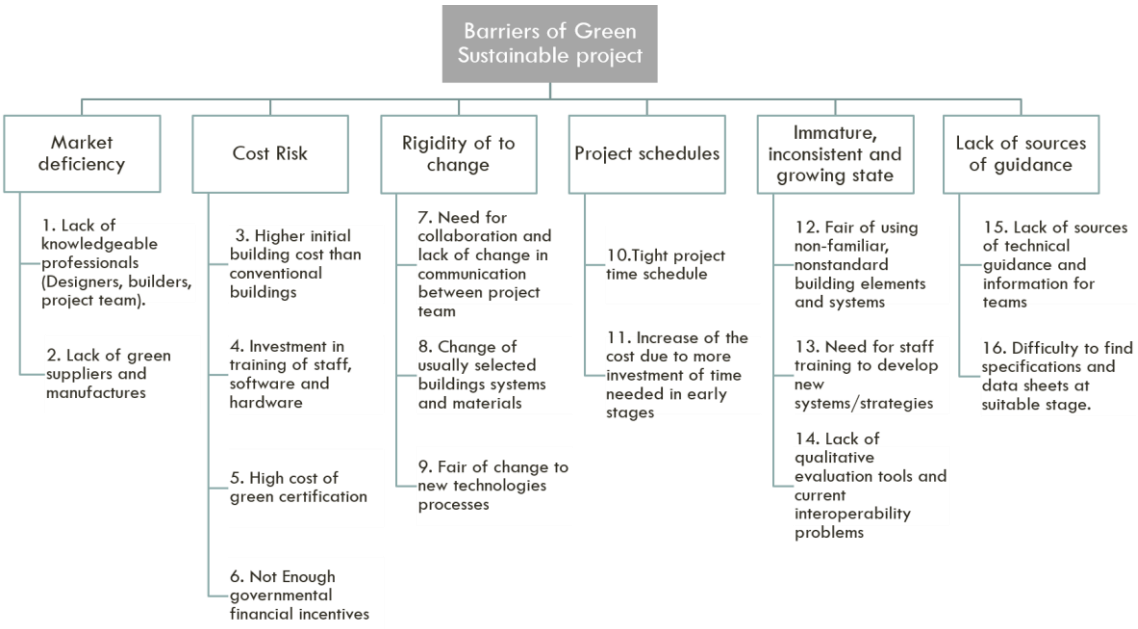


**Figure 3. Barriers to deliver sustainable buildings**

Balasubramani (2017), demonstrated the relation between the drivers and barriers of green practices to the development needed with respect to stakeholders in the industry in core building practices and facilitating green practices. Also, recommendations were proposed in different studies to overcome barriers by promoting the benefits of developed markets (Wimala, Akmalah and Sururi, 2016; Nguyen *et al.*, 2017). For the literature, researchers agreed that it is essential to focus improvements on different tracks to overcome green building (GB) barriers. As mentioned in Hopkins published paper in 2016, it was argued that : altering perspectives of practices, targeting development of universities education, changing policies, finding ways of funding for GB financial incentives are possible solutions. In addition,

improving ways of GB delivery to overcome processes efficiency in terms of extra cost and time could be a motivation for stakeholders to adopt GB practices.

### 3.3 Growth of BIM use in AEC

Another significant observation in the last decade, highlighted by many studies, is the growth of adopting BIM technologies.(Tulubas Gokuc and Arditi, 2017) BIM is promoted as set of policies, technologies and process that allows project team to work in proactive decision making environment (Razkenari, Nanehkaran and Barati, 2016). The main driver of the practice growth and significant research interest is the paradigm shift that BIM technologies offer in ways of visualizing, organizing, analysing, simulating building performance and documenting project information. The fundamental strategy to ensure collaboration within BIM process is to have centralized, defined, structured, and easy exchanging data environment. This strategy is still in process of developing to enhance the work efficiency of the construction sector that is suffering from fragmentation of work, multi participants' process, increasing complexity and use of variety of systems and technologies. However, consistent framework with respect to sustainability application has not been established yet.

### 3.4 Driving Forces for Collaborative Building Design Adoption

The main driver pressuring the need for change in AEC industry, is the criticism on the significant amount of waste in project life cycle. (Saad Sarhan and Christine Pasquire and Andrew King, 2017) This waste could be physical, such as waste of materials or primary waste for example waste of time and effort in rework, disputes and delays. It is also blamed for the slow progression over the last 60 years in terms of efficiency(Saad Sarhan and Christine Pasquire and Andrew King, 2017). Therefore, research and practice are driven by the idea of increasing the value for all stakeholders with less effort, time and cost, it is proved that collaboration is the key to achieve this aim. (Venkataraman and Cheng, 2014)BIM capabilities enable effective collaboration between different disciplines, but at the same time unsatisfactory percentage of the use of BIM in sustainable projects within practice is reported in recent studies. BIM revolutionary technology and processes are explored in multiple of studies towards creating harmony among project team. (Azhar and Brown, 2009b) Zanni, Soetanto, & Ruikar, 2017) Different tracks of development to support the potential of BIM were attempt to be addressed in order to enhance efficiency in workflow as shown in Table2.

Multiple studies in the last 10 years discussed the problems in traditional methods for green project delivery and pointed out potentials of the synergy with BIM (Hope and Alwan, 2012; Alwan, Greenwood and Gledson, 2015b; Luo and Wu, 2015). Accordingly, authors in the field focused on different development areas to benefit from the potentials of the synergy. The work of the leading authors in the field could be clustered into studies that focus on:

1) Tools capabilities in Modeling, simulation, visualization and automation.
2) BIM and Sustainability Framework and Management.
3) Enhancing information management and decision support for EAM.

It could be claimed that the above themes were evolved from the trending approach in the use of BIM which is reducing manual inputs and effort of work by developing automotive ways

of producing information outputs from models. Also, utilizing BIM approach of having a structured, well-coordinated process with assigned responsibilities with manageable framework is important approach. Studies recently addressed benefiting from BIM model in its parametric state by developing scripts to automate variety of outputs such as quantities' and link them to the cost estimate (Choi, Kim and Kim, 2015). Using similar concept of automating outputs from the green building assessment models were developed in more than one study. These studies explored the utilization of BIM models to automate the estimated achieved EAM credits (Wu and Issa, 2012; Jalaei and Jrade, 2015; Ilhan, Bahriye, 2016). Other studies such as Lim in 2015, (Lim *et al.*, 2015) published study that attempted to map the sustainable design strategies with required the level of development (LOI and LOD)of the BIM model for effective integrated process driven design based on performance. It can be observed that similar studies that are trying to map the level of detail (LOD) and Level of information (LOI) are very limited. It can be concluded that the literature shows more focus on development of software and tools, rather than process and workflow.

**Table 2 Topics discussed by leading authors**

| Theme | Discussed topics | References |
|---|---|---|
| **1. Focus on Software** Tools capabilities in Modeling, simulation, visualization and automation | Simulation of building environmental performance- Energy, carbon, daylighting, LCA | (Wang *et al.*, 2017) (Stapleton, Gledson and Alwan, 2014b) (Ajayi *et al.*, 2015) |
| | Parametric properties and use of model for generation of automated outputs related to credit calculations. | (Wu and Issa, 2012) (Ilhan, Bahriye, 2016) (Jalaei and Jrade, 2015) (Han *et al.*, 2017) |
| | Reporting problems in Interoperability and proposing solutions | (Wong and Fan, 2013) (Moon *et al.*, 2011) (Lim, 2015) (Lu *et al.*, 2017) |
| **2. BIM and Sustainability** Framework and Management | Use of BIM-based sustainability analysis in different stages | (Wong and Zhou, 2015) (Lu *et al.*, 2017) |
| | Level of definition with respect to sustainability check points workflow | (Lim *et al.*, 2015) |
| | Input for BIM execution plan and responsibility matrix: Responsibilities, roles and deliverables | (Azhar and Brown, 2009b) (Gerrish, 2013) (Zanni, Soetanto and Ruikar, 2017) |
| **3. BIM for Green Certification** Enhancing information management for green certification | Process mapping and integration of BIM work and work needed to achieve credits | (Wu and Issa, 2013) |
| | BIM contribution in EAM delivery-assessment of use of BIM to achieve EAM credits | (Wong and Kuan, 2014) (Salman Azhar *et al.*, 2011) (Alwan, Greenwood and Gledson, 2015b) |
| | Common data environment and digital plan of work relation to EAM | (Ayman, Alwan and Marzouk, 2017) (Harding *et al.*, 2014) |

Unfortunately, although the high potential explored in different directions of development in research, a gap is found in application in practice. Limited studies have found on developing execution plan of BIM- based sustainability that was based on the problems and deficiencies in workflow captured from industry practices.

### 3.5 Barriers of BIM-based sustainability

Despite the great potential and benefits mentioned above, unsatisfactory levels of adoption is observed due to the practice barriers.(Olawumi and Chan, 2018) It is recognized that common barriers are found in literature between BIM and sustainability implantation, which is related that they are both new changes in practices in the industry, shown in fig. 4. Previous research reported the same factors as mentioned of sustainability barriers, BIM adoptions obstacles in the market are the lack of skilled professionals, risk of initial investment, rigidity to change, lack of inconsistent framework that is derived from the growing immature state (Oduyemi, Okoroh and Fajana, 2017). On the other hand, some barriers; which are considered problems facing project team in delivering sustainable buildings, are demonstrated to be overcame with the potential utilization on BIM. Researchers claim that by adopting BIM based sustainability project design, construction and operational cost can be reduced as well as saving effort and time, by improving the work efficiency. This is achieved through the capabilities of tools and processes to eliminate conflicts, reduce rework, avoiding errors and omissions through visualization, coordination and structured framework. On the other hand, one of the main factors that benefits of BIM affect the initial productivity of the staff, due to time spent on learning process and discovering the problems in applying new approaches in work. Also, there is a significant influence between the relation of the client demands, satisfaction of the existence service and competition level among the professionals industry. (Eadie *et al.*, 2013) Some studies claim that this relationship on competition in market and non-satisfying service of traditional project delivery are influencing the rise of client demand to apply BIM within integrated project delivery. (Arunkumar, Suveetha and Ramesh, 2018a). But at the same time still the Immature and inconsistent framework for applying sustainability aspects within BIM protocols responsibilities, roles and deliverables, in addition to the lack of rational mechanism for checkpoints through project lifecycle are considered the main organizational obstacles (Zhao *et al.*, 2017).

The listed barriers are the most common, repeated in the review papers that evaluated their influence on the adoption of BIM in the industry, which will directly affect BIM based sustainability as well, as shown in Figure 4. Additional to the barriers of BIM based sustainability which is common to BIM, other internal barriers are only related to BIM based sustainability. In Figure 4, the additional barriers are categorized under technological, legal and extra initial cost. One of the highlighted barriers are the level of accuracy of the simulation of the energy and building performance tool and risk of reliability on them (Arunkumar, Suveetha and Ramesh, 2018b). These were addressed by comparing the predicted energy extracted by simulation tools and the actual energy consumption produced by post occupancy evaluation.

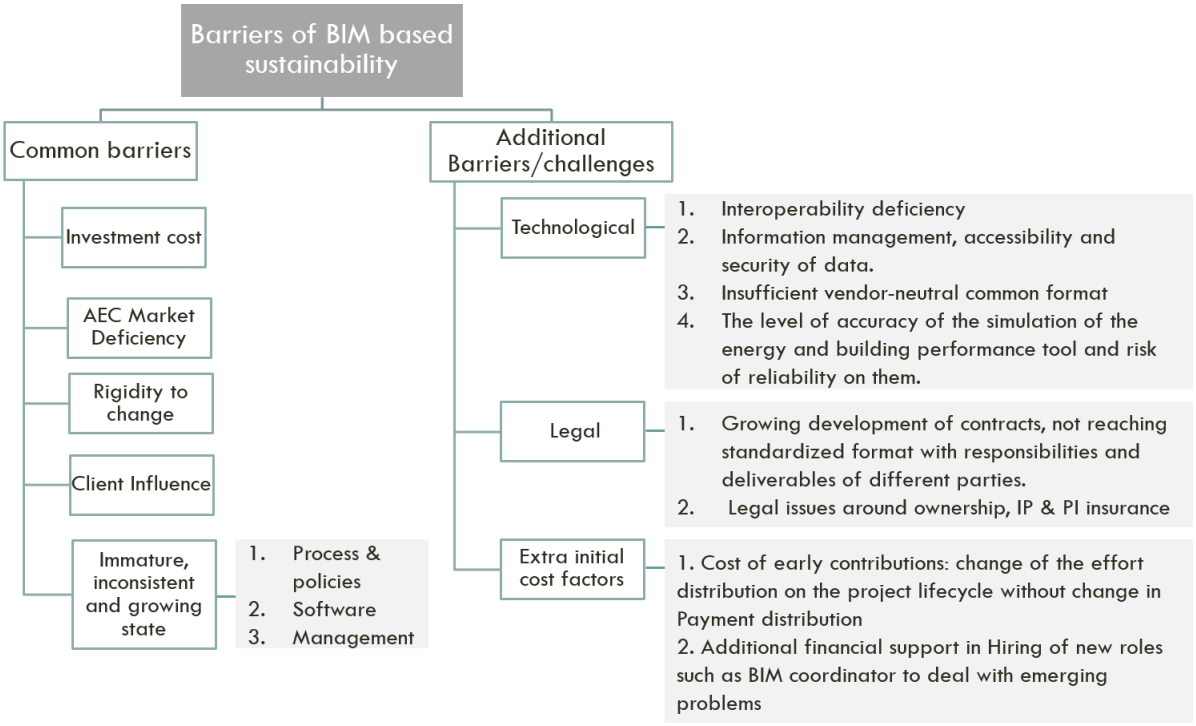


**Figure 4. Common and Additional Barriers of BIM based Sustainability**

## 4. Bridging the Gap between BIM and Sustainability

The correlation between the barriers for adopting green practices and benefits of BIM integration need to be highlighted. In order to bridge the gap between BIM and sustainability practices first the stakeholders need to be aware by the direct and indirect contribution of BIM in the short and long term. Then areas of development to reach consistent integrated design and execution method need to be identified. This section will discuss the expected impact of BIM, the problem in current practices and areas of development to achieve integrated method.

### 4.1 Direct and Indirect Impact of BIM based sustainability Adoption:

BIM has been identified as having characteristics for improving collaborations on project delivery. After reviewing the demand factors affecting the adoption of BIM based sustainability, it can be argued that the development in the BIM for delivering sustainable projects have direct and indirect impact to reduce the barriers of adoption. The first direct influence is guidance support environment that BIM framework offers to the project team for the responsibilities and the use of models and simulation results. Also, the approach of the digital plan of work (*RIBA Plan of Work 2013*, 2013)(BSI, 2013) of the Information process through streaming, documenting graphical and no graphical data will allow project team to use and reuse previous project data. It can concluded from literature that the

predicted direct impact of the potential use of BIM on the sustainability barriers can be listed as follows:

1. Decrease the risk of extension of project schedules due to repeat of work by ensuring design coordination, well communication and consistency.
2. Providing decision support framework for team guidance linked to the use new technologies and possibility of linking it to elements of the BIM model.
3. Compensating the high initial cost of the use non-convention green solutions by reducing the variation cost due to early collaboration.

The indirect influence will be on the market growth, covering the deficiency in both green suppliers and knowledgeable professionals. It is predicted that this will be achieved through the perceived higher value of service to client provided by professionals applying BIM. The high competition in market and need to increase the value of services to the clients will gradually impact the market deficiency in green suppliers, knowledgeable professionals and rigidity to change. The fair of the loss of competition and market share will gradually influence more practices to change their perspectives to provide the clients by their needs.

### 4.2 Problem in Current Practice

This paper allowed us to highlight the areas that need development in order to enhance the status of the synergy between BIM and sustainability. Figure 5, illustrated the main findings of this paper, which align the potential contribution of BIM to overcome some of the sustainability barriers. In order to perceive the synergy benefits, investigation is require for practice acceptance to new technologies to shape the development of mechanisms for change.

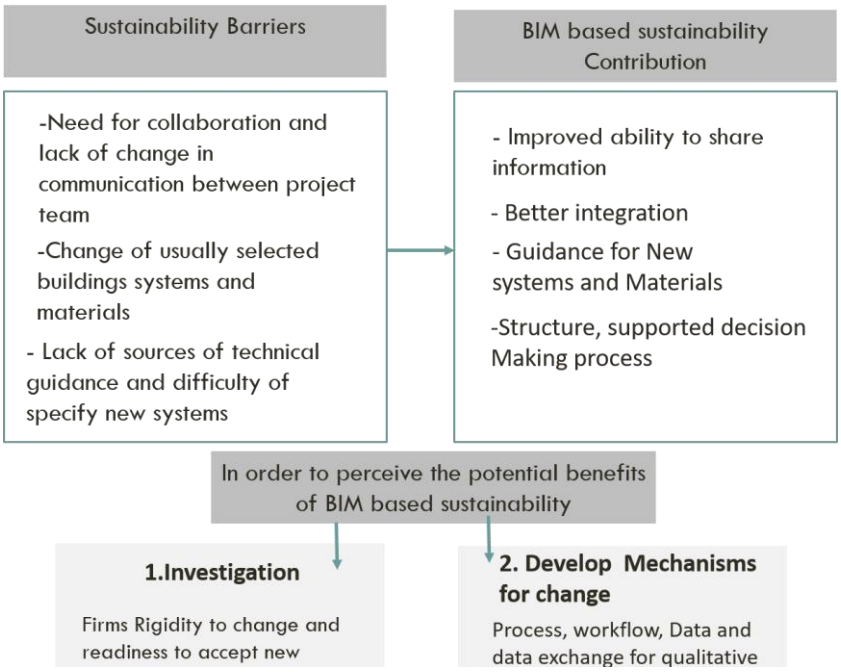


**Figure 5 BIM based contribution and area of development**

Improved collaboration targets are currently set for sustainability aspects), but are outside the BIM framework. Organizational aspects in terms of process, responsibilities, deliverables and communication for green building practices need to be investigated. Also, exploring the use of emerging tools for efficient integration are required to be able to contribute in reducing the barriers to deliver sustainable buildings. Accordingly, the alignment of sustainability and BIM strategies is crucial to maximize the perceived efficiency benefits of both the building performance and project workflow efficiency.

RIBA published green overlay in 2011 to the old version of the outline plan of work. (Gething, 2011)Although work for attaining credits in BREEAM are aligned in theory along the RIBA work stages, the practice is suffering from the divorce of the sustainability aspects within the BIM management process. Therefore, further work is needed to find mechanisms to motivate the change towards successful integration. This can be attained through improved ability to share information, in addition better access to the required information and guidance documents. Prior study was conducted by (Ayman, Alwan and Marzouk, 2017), which provided insight on disconnection between sustainability and BIM process. The findings presented deficiencies in the applications of theoretical framework suggested by RIBA and BRE that integrate the BREEAM credits on the stages in UK. Setting detailed sustainability targets, not applying early collaboration and considering sustainability aspects in late stages were the main findings highlighted in this study.

### 4.3 Further work and Mechanisms for Change

Further work is required in order to bridge the gap between BIM and sustainability to overcome this disconnection. First, a holistic picture need to be drawn on the current problems of green building delivery, using flied work investigation. Then, perceived benefits and the ease of use of possible synergy solutions need to be evaluated. Afterwards, a framework should be developed accordingly. This framework should allow project team to align the sustainability targets and criteria with critical decision points within BIM execution plan. Also, the work should investigate readiness of firms to accept change. The analysis of the current state of practices BIM-based sustainability, in addition to the future perceived benefits of adoption could act as indicators for future field acceptance to changes. The theory of Technology acceptance model (TAM) developed by Davis 1989 (Venkatesh and Davis, 2000) could be used to model the factors that influence the user acceptance to new technologies, TAM presented in fig. 6. Based on this theory a BIM-based sustainability acceptance model can be developed to be able to establish the mechanisms for change.

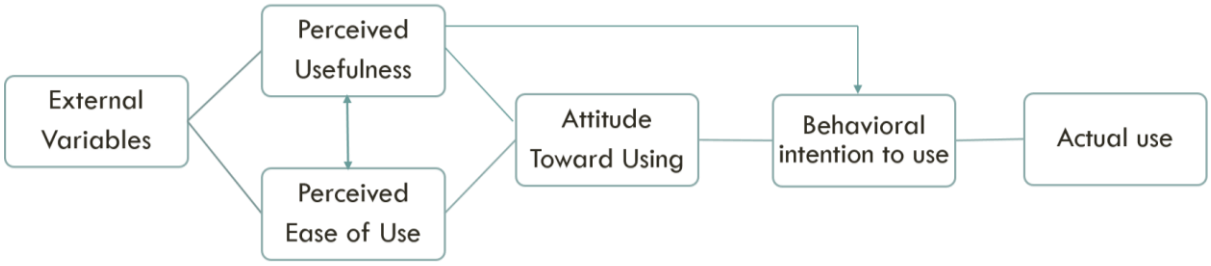


**Figure 6 Technology Acceptance Model** (Chuttur, 2009)

## 5. CONCLUSION

The purpose of this paper was to articulate the reasons behind AEC industry change in perspective and altitude. The drivers for adopting collaborative and green strategies in construction have been acting as a catalyst to change in the dynamics of AEC industry. This has resulted in the increased development and use of BIM based sustainability models. Focused on the driving forces and barriers of sustainability projects, and also adopting BIM, this study analysed and indexed the common categories that were discussed in previous literature. The relevance of the increasing recognition of the synergy benefits is clearly supported by the evolution of different themes in academia that are trying to deal with industry complexities. Yet, it is acknowledged that the synergy of BIM with sustainability aspects will not solve all the problems in construction industry efficiency, and other external obstacles highly affect the development. The findings of this paper provided insight into the areas that need development to reach a consistent and mature level of integration between sustainable aspects and BIM process. Essentially, it has been argued that more development is required in capturing the practice struggles with the alignment of sustainability work with the BIM process in terms of workflow, process, communication patterns, data, and data exchange. Other finding for the paper is gap that found in literature in providing solutions and framework for the synergy developed from the problems reported by the industry with dealing and testing sustainability. Further work is required to analyse real-life project problems to reach sufficient framework. In addition, testing the impact of change in practice approach by investigating qualitative and quantitative perceived benefits and ease of use is crucial. This could be used as evidence to promote for BIM-based sustainability and predict technology acceptance rate in field work.

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